# QUARTERLY PROGRESS REPORT

**PREPARED FOR THE ALASKA ENERGY AUTHORITY**
**BY**
**CHENA POWER COMPANY**

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| **PROJECT TITLE:** | Chena Power Geothermal Power Plant |
| **COVERING PERIOD:** | July 1st through September 30th, 2005 |
| **DATE OF REPORT:** | October 23, 2005 |
| **GRANT RECIPIENT:** | Chena Power, LLC<br>P.O. Box 58740<br>Fairbanks, AK 99711 |
| **AWARD NAME:** | Alaska Energy Cost Reduction Solicitation |
| **AWARD AMOUNT:** | $246,288 |
| **PROJECT PARTNERS:** | United Technologies Corporation<br>411 Silver Lane<br>East Hartford, CT 06108 |
| **CONTACT(S):** | Gwen Holdmann, Chena Hot Springs Resort<br>PO Box 58740<br>Fairbanks, AK 99711<br>office # (907) 451-8104; cell # (907)590-4577<br>*gwen@yourownpower.com* |
| **PROGRAM MANAGER:** | Rebecca Garrett, Alaska Energy Authority<br>813 West Northern Lights Blvd<br>Anchorage, AK 99503 |

**PROJECT OBJECTIVE:**

The objective of this project is to install a 400kW Organic Rankine Cycle (ORC) geothermal power plant at Chena Hot Springs, Alaska. This will be the first power plant operated off fluid from a geothermal resource in the State of Alaska, and will serve as a demonstration of the technology in this state. Additionally, the geothermal power plant will replace a 200kW diesel Caterpillar genset, displacing $241,812 of diesel fuel annually[1].

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[1] Based on current fuel cost of $2.50 per gallon, and current rate of use. This number has been revised upward since 2003 by 150%.

## EXECUTIVE SUMMARY

Work on the 400kW geothermal power plant to be installed by Chena Power Company has focused on six main areas during the last quarter. These include:

1. Working on system design with the manufacturer
2. Resource development and testing
3. Preparing and building onsite infrastructure necessary for operation of ORC[2] units
4. Preparing for electric hookup of ORC units to existing power plant and grid system
5. Obtaining necessary permits
6. Obtaining utility certification

This report will provide an update on each of these areas of focus, organized as Part 1-6.

Originally, the first ORC unit was scheduled to be installed by December 2005. However, due to delays caused primarily by a change in manufacturer and in meeting requirements set forward by AEA to obtain utility certification under Chena Power Company, the project has been delayed 6 months to installation of the first 200kW module, and one year until installation of the second module and completion of the project.

After considering two other manufacturers, United Technologies Corporation (UTC), based in Hartford Connecticut, was selected as the manufacturer of the Chena Power system, using components from Carrier Refrigeration chillers. The President of Chena Power, Mr. Bernie Karl, visited UTC and Carrier in October, 2004, to inspect the production facilities. The power plant will be built as two 200kW ORC modules at the UTC Research Center in Hartford, then disassembled and shipped to Chena Hot Springs in two separate installations planned for June and November, 2006.

The project budget has been revised upward to $2,462,145[3] from the original budget of $2,145,353. The increase is due primarily due to higher expenses than anticipated for onsite construction in support of the project. However, United Technologies Corporation has received a partial grant in support of their product development[4]. This grant will cover $438,902 of the cost of the power plant, reducing the actual power plant cost for Chena Power to $250,000. This will reduce overall project costs for Chena Power below the initial cost estimates.

[2] ORC = Organic Rankine Cycle
[3] Based on the grant notification letter to Chena Power dated August 23, 2005
[4] The grant awarded to UTC is part of the Department of Energy's 'Geothermal Electrical Power System Validation', and the contract number is DE-FG36-05GO15151

## PART 1: CHENA GEOTHERMAL POWER PLANT SYSTEM DESIGN

The Chena Hot Springs geothermal power plant will be designed and manufactured by United Technologies Corporation based on the technology and hardware from the commercially available PureCycle™ 200. The PureCycle™ 200 is an Organic Rankine Cycle plant that is designed to produce 200kW of electric power from waste hot gas sources between 500 and 1000°F. It is manufactured using mass-produced Carrier chiller components[5] including a single-stage centrifugal compressor running in reverse as a radial inflow turbine producing 200kW of power and heat exchangers originally designed for large chiller applications. The geothermal application for the PureCycle™ platform is a natural extension of the existing product, and Chena Hot Springs will be the first geothermal site the product will be installed at.

The geothermal plant module will be designed and qualified at the United Technologies before installation at Chena Hot Springs. The turbine and heat exchangers will be procured from and manufactured by Carrier's large chiller manufacturing facilities. Manufacturing will be closely monitored in order to verify the projected manufacturing cost of the power plant. The plant will be installed in two steps at Chena Hot Springs. The first 200kW module will be installed in June 2006 followed by a second unit in November of 2006. UTC will be closely involved in operation for the first two years in order to validate operation and maintenance costs. Local and remote monitoring will be applied for both operation and data collection.

Because the geothermal resource at Chena Hot Springs presents a unique set of design criteria, the following modifications to the PureCycle™ 200 plant will be made:

- The working fluid will be change from R245fa to R134a. This fluid is a better match for low temperature geothermal applications and enables a significant cost reduction, both directly because R134a is a low cost fluid widely used in HVAC equipment and indirectly by allowing lower cost commercially available components to be used in the power plant.
- Low cost heat exchangers specific to geothermal applications will be developed based on designs and production capability in place for Carrier's large commercial and marine water-cooled chillers.
- The plant cost relative to the Air-Air PureCycle™ ORC plant will be lowered by incorporating and qualifying more commercially available components, which is made feasible by the lower operating temperature in geothermal applications.
- Control algorithms and methods for operation will be developed with tube and shell heat exchangers rather than the fin-tube technology applied in the Air-Air PureCycle™ plant.

The preliminary equipment sizing was conducted to insure that the geothermal resource could produce 400kW, and that the equipment could be manufactured within an acceptable timeframe. The requirement to produce 400 kW can be met by various

[5] Carrier Refrigeration is a sister company to United Technologies Corporation

combinations of geothermal flow and temperatures. In consideration of the testing completed on the geothermal reservoir[6], the design point numbers for the reservoir were chosen to be:

Flow rate = 1060 gpm,
Inlet Temperature = 164°F entering
Outlet Temperature = 130°F leaving

This was based on results from a flow test conducted August 6th, 2005[7]

For low temperature water-cooled geothermal applications such as those at Chena Hot Springs, R134a is predicted to be the best Hydro Fluorocarbon (HFC) working fluid. This fluid allows the use of the existing Air-air PureCycle ™ 200 turbogenerator, which was derived from the Carrier 19XR2 centrifugal compressor platform, with minimal modifications.

R134a is a readily available refrigerant. It is also the working fluid in Carrier's 19XR line of water-cooled centrifugal chillers. The tube-and-shell heat exchangers of this product line can be used as ORC evaporators and condensers. This allows a packaged ORC power plant design as opposed to the split-system design of the currently available Air-Air PureCycle ™ 200 ORC unit. Thus the proposed geothermal ORC system will be very similar to Carrier 19XR water-cooled chillers enabling installation to be performed from an existing pool of mechanical contractors.

Preliminary cycle analysis shows that with the 164°F temperature geothermal liquid as the heat source and 40ºF water from an infiltration gallery as heat sink, two geothermal power plants can be developed with HFC134a as the working fluid. The proposed power plants will each operate at the following conditions:

*Water side*

| | | | |
|---|---|---|---|
| Heat source: | Tin = 164 °F | Tout = 130 °F | Flow rate: 530 gpm |
| Heat sink: | Tin = 40 °F | Tout = 50 °F | Flow rate: 1614 gpm |

*Refrigerant side*

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|---|---|
| Mass flow rate: | 26.8 lbm/s |
| Evaporator/turbine inlet pressure: | 232 psia |
| Condenser/turbine exit pressure: | 63.6 psia |
| Turbine gross power: | 230 kW |
| Pump power: | 40 kW |
| System output power (net): | 190 kW |
| Thermal efficiency: | 7.4 % |

[6] See **Supplemental Attachment #1**: *Initial Geothermal Resource Evaluation*, prepared by David D Faulder, PE for Chena Hot Springs.
[7] see **Part 3** of this report: Resource Testing and Development, beginning on page 8.

These numbers are derived from actual component efficiencies for the turbine and pump, reasonable line losses and conventional log-mean temperature differences in the heat exchangers.

In referring to **Figure 9.**, on the preheater/evaporator side of the ORC system 530 gpm of 164 °F hot water (point A) enters the unit and is cooled to 130 °F (point B) transferring 2.58 MW of thermal energy to the refrigerant. This energy preheats the 26.8 lbm/s refrigerant mass flow rate from 54 °F (state point 4) to 136 °F and subsequently boils the working fluid at this temperature before slightly superheating it (state point 1). The high-pressure refrigerant vapor is expanded in the turbine that extracts 250 kW of mechanical power from the refrigerant flow at 80% aerodynamic efficiency. After accounting for mechanical and electrical losses 230 kW of electrical power is delivered by the generator. The refrigerant vapor leaving the turbine (state point 2) is de-superheated, condensed at 53 °F and then slightly subcooled to state point 3 in the 2.36 MWth water-cooled condenser. The condenser heat is transferred to 1615 gpm of 40 °F cold water (point C) that is heated to 50 °F (point D). The refrigerant loop is closed by a pump, which elevates the refrigerant pressure from 65 psia (state point 3) to 245 psia (state point 4). The proposed 35% efficient pump requires 40 kW of electrical power. Accounting for all losses, the net power produced by this ORC system is 190 kW, which equates to a net thermal efficiency of 7.4%. This efficiency is quite a challenge given the limited thermodynamic availability of the low temperature geothermal heat source. A completely reversible thermodynamic cycle working with the same heat source and heat sink temperature glides would have a thermal efficiency just under 18%. Major components of the ORC system were sized based on the cycle analysis elaborated above.

Additional information on the PureCycle ™ 200 or the modifications being made to the system for the Chena Power geothermal plant can be provided upon request.

## PART 2: UPGRADES BEING COMPLETED ON EXISTING POWER PLANT IN PREPERATION FOR CONNECTING TO GEOTHERMAL POWER PLANT

In preparation for connecting the existing power plant to the geothermal power plant, several changes need to be made to the current configuration of the power plant. These include: Installation of batteries and UPS system, paralleling of generators, and restraping diesel generators to 480VAC to match output from ORC modules.

### Battery Bank/ UPS System

Installation of a 1500kVA battery bank and UPS system are necessary for two reasons. Firstly, this will allow power production from multiple sources (primarily the ORC units and the paralleled generators) to smoothly and continually provide power to customers, via the inverters which are part of the battery/UPS system. Secondly, the ORC unit uses an induction generator, which requires a stable input voltage and frequency for startup, which can be provided by the inverter output. UTRC has previously tested this type of system. The 480V inverter which is part of the UPS system can provide voltage and frequency to the induction generator as it extracts current. This type of system, with batteries for startup and load balancing, allows for the grid-independent operation required by Chena Power.

The battery bank and UPS system were purchased and moved onsite in June, 2005. The manufacturer of the system is MGE, and the model is the EPS 6000 UPS Module[8]. The system has been installed in four Conex units and has been wired to the UPS system by Chena Power employees, under the direct supervision of Bernie Karl (see **Figure 1, 5, 6, 7**). The UPS system is now being hooked to the grid and the diesel generators are being connected to the batteries. The manufacturer of the UPS system, MGE, will send a representative to Chena in November, 2005 in order to program the system controllers and commission the system. The batteries will be online and all power will be provided through the UPS system by the end of November.

### Paralleling of Diesel Generators

In preparation for the installation of the ORC geothermal power plant, the three existing generators for Chena Power are being paralleled. Originally, they were configured in series with only one of the three Caterpillar 3306 200kW providing grid power at any one time (see **Figure 2**). Paralleling the existing generators is necessary for a number of reasons. The ORC geothermal power plant will have some parasitic load associated with it, due primarily to pumps for the hot and cold water supply, as well as reinjection of the geothermal fluid. Internal system loads are accounted for and the net output of each unit will be 200kW, however the grid requirement will almost certainly average over 200kWhr once the geothermal plant is on line. Therefore, parallel operation will be required during high load timeperiods. Once the ORC units come online, they will take the place of the paralleled generators. (see **Figure 3, 4**) The existing diesel generators will remain in place and paralleled with the ORC units to provide emergency backup. Estimated date of completion is November 1st.

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[8] The original grant application includes technical specification for the MGE UPS system

Steps completed in paralleling of generators:

- Installation of new governor controls
- Installation of synch scope
- Installation of synch lights
- Installation of reverse current relays

**Restraping Diesel Generators to 480VAC Output**

Because the ORC Geothermal Power Plant is designed to produce an output voltage of 480VAC, it is necessary to switch the entire primary grid for Chena Power to 480VAC output. In addition to restraping the generators, this will require the installation of new power transformers (480 → 120/208) and a new 480VAC control panel. Expected date of completion is November 1st. The work is being completed by Dick Gallison (see **Figure 7**).

**Installation of New Double Walled Fuel Tank and Day Tank**

Chena Power has installed a new double walled fuel tank to replace the previous single walled tank with liner. Additionally, a day tank has been installed to pre-warm diesel fuel and increase accuracy of monitoring daily fuel consumption (see **Figure 8**). This is not directly related to the geothermal power plant project and is not included in the project budget, but is part of Chena Power Company's effort to upgrade the existing system.

## PART 3: RESOURCE DEVELOPMENT AND TESTING

### Resource Testing

Chena Hot Springs Resort has been undertaking an extensive evaluation of the resource in order to ensure that the shallow geothermal reservoir is capable of sustaining prolonged extraction of geothermal fluid without any harmful consequences to the geothermal system.

In support of this project, an assessment of the geothermal resource of Chena Hot Springs geothermal was completed by Dr. David D. Faulder of SAIC[9]. Dr. Faulder's report describes flow tests that were performed using 6 shallow geothermal wells that were drilled between 1998 and 2003.

The information gained from both these recent tests and from previous resource evaluations completed in the late 1970's and early 1980's was used to develop a three dimensional numerical model of the Chena Hot Springs hydrothermal system. This model was used to determine the potential impact that a production of 1060gpm at 164°F would have on the existing thermal features. Dr. Faulder's conclusion was that this source would be sufficient to operate two 200kW ORC power modules for a total of 400 kW. Additionally, the optimal choice for a re-injection well was assessed.

### August 6th, 2005 Flow Test

Since this report was completed in May, 2004, a second more extensive flow test was conducted on the proposed production well on August 6th, 2005. This test was designed as a 12 hour flow and pressure interference test on geothermal production Well #5. This well has been pumped almost continually since May, 2003, for the district heating system and operating an absorption chiller. In the past, the well has been allowed to flow artesian at a rate of 500gpm for periods up to a week. During this flow test, air assist was used to flow the well at 1100gpm throughout the duration of the test (see **Figure 11**). During the test, Well #0 was simultaneously being pumped at a rate of 150 to 200gpm, for a total withdrawal from the shallow geothermal reservoir of 1250gpm.

During the flow test, temperatures and pressures were measured in 3 observation wells (temperature gradient holes) for a total period of 90 hours, including pressure drawdown and buildup (see **Figure 10**). Observation wells during the flow test were:

- TG1: Drilled depth of 74 ft, located 100ft to the SW of Well#5
- TG3: Drilled depth of 214 ft, located approximately 500ft W of Well#5
- TG4: Drilled depth of 210 ft, located approximately 1500ft E of Well#5

The flow test was started at 4:40pm on August 8th, and water was discharged from the well into a weir box to measure the flow rate. The well output was limited by the size of the weir box. The produced fluid temperature, flow rate, conductivity and TDS values were sampled at intervals. All of these values remained static throughout the test, with

[9] *Chena Hot Springs Initial Geothermal Resource Evaluation*, the C.V. for David D. Faulder are included as supplements to this quarterly report.

the exception of the temperature of the produced fluid temperature, which increased 3ºF during the first hour, and then stabilized at 165ºF for the duration of the test.

The level in the weir box was averaged between the two sides and found to be 9-1/2 to 10 inches, equivalent to 1100gpm of flow. TDS (total dissolved solids) was measured at 400ppm, and the conductivity was measured at 550 µS. Neither value changed noticeably during the test, indicating the flow was from the shallow mixing zone throughout the test.

Once the flow test and a 32 hour pressure recovery period was completed, the temperature and pressure gauges were pulled from the observation wells. TG#3 showed no discernable change in temperature or pressure during the test (see **Figure 12**). A general pattern of slight and consistent increase in pressure is most likely due to barometric pressure changes. The gauge also showed some anomalous readings 20 and 42.5 hours into the test, which are signal noise and will be disregarded in analysis.

TG#4 showed an interesting result (see **Figures 13** and **14**). There was a clear period of draw down of approximately 1.5psi, during which there was a noticeable increase in temperature of approximately 4ºF. This suggests that fluid is being pulled from a nearby hotter regime, and suggests hotter water may underlie or be otherwise located in close proximately to the gradient hole.

TG#1 Showed an interesting behavior before, during and after the flow test. Slight variations in pressure were closely mirrored by changes in temperature. This is because the well is only drilled to 74ft, and cold water is being drawn into the well-bore. This was accentuated during the flow test.

**Water Sampling**

In addition to the flow tests completed above, water samples were collected from six geothermal and four cold wells at Chena Hot Springs, along with streams and springs in the immediate area, to be used for conventional chemical and isotopic analysis. The sampling shows that the water meets drinking water quality standards, and that the geothermal fluid is well mixed and indistinguishable isotopically between the geothermal and even some of the cold water wells.

**Temperature Gradient Studies**

A regular series of temperature gradients and pressure measurements from the wells at Chena have been collected. This data will assist in establishing baseline conditions for the reservoir, and for making decisions in choosing which of the existing wells are most attractive for reinjection testing.

**Conclusion from Testing**

Several important conclusions can be drawn from the available data:

1. A pressure drawdown of approximately 1.5psi was seen in the geothermal reservoir during drawdown testing, but pressure recovery was relatively fast suggesting good permeability and recharge rate into the shallow reservoir.

2. No decrease in production well temperature was observed during any of the testing, and during the flow test on August 8th an increase in temperature was observed in TG#4. This suggests it is reasonable to set a system design temperature of 165°F.
3. The pressure drawdown during flow testing resulted in decreased flow from the natural hot springs, which would be minimized through the reinjection of the fluid back into the reservoir.
4. During the interval tested, no inflow of cold water was observed, which suggests production from the existing shallow wells should be sustainable over the long term. More testing is required to establish this with certainty; however the problem of potential cold water inflow with decreasing reservoir pressure could be eliminated by drilling deeper production wells in the future, and by fine tuning a reinjection strategy.

**Reservoir Development**

Chena Hot Springs has established numerous observation holes to make long term downhole temperature measurements of the shallow reservoir. This will allow monitoring of the reservoir to make adjustments to production and reinjection strategies once the power plant is online.

The production well has been completed and cemented in preparation for installation of the power plant. A submersible pump adequate for pumping 1000+gpm has been selected from Energy Supply and will be ordered during the next quarter.

# PART 4: ADDITIONAL ONSITE INFRASTRUCTURE

In preparation for installation of the power plant, a substantial amount of onsite infrastructure needs to be built to support the operation of the ORC system, and to transport the geothermal fluid from the production well to the power plant. This infrastructure includes:

1. Erecting a new power plant building to house the power plant
2. Installation of a pipeline from the production well to the power plant
3. Design and Installation of a cold water supply and discharge system

There are also substantial upgrades being made to the current power plant in preparation for marrying it with the ORC modules. This is covered in Part 4 of this report.

**Power Plant Building**
The foundation was completed and a heated cement slab was poured for the power plant building in September, 2005 (see **Figure 14**). The slab is 6in thick to accommodate the manufacturer requirements. The new power plant is being located adjacent to the existing diesel power plant.

The power plant building is a premanufactured steel building with two 3 ton overhead cranes – one for each ORC unit, and a separate control room. Large overhead garage doors will be installed to accommodate equipment needed for installation of the ORC units and possibly for future maintenance. The building in being moved onsite at the time of this report, in preparation for erecting the structure. The building is expected to be completed early in 2006.

**Pipelines**
Both the hot and cold water supplies will be piped through 8in diameter insulated HDPE pipelines. Expected pipeline distance for the hot water supply is 1500ft, while the cold water supply will be approximately 400ft. Return pipelines will also be insulted HDPE. There will be two return lines for the hot water supply to distribute reinjection between two wells. The cold water may be returned to Monument Creek via a ditch or larger diameter pipeline.

Both of these pipelines will be installed in May and June of 2006, just prior to installation of the first ORC module.

**Cold Water Supply Infiltration Gallery**
The power plant will be water cooled, and as such will require 1500gpm per unit of 40°F water. This water will be obtained from an infiltration gallery (see **Figure 15**) located on the North side of the property and pumped to the power plant via an 8in diameter insulated pipeline. The infiltration gallery is designed to be 56in diameter and 25ft deep. Once the water is used for cooling in the power plant, its temperature will be raised 10°F and discharged into Monument Creek, upon completion of permitting through DEC. This system is expected to be completed in May, 2007.

## PART 5: PROJECT PERMITTING

A number of permits are necessary for this project. They are listed below, along with an update on the status of each one.

### Water Rights Permitting

Agency: Alaska Department of Natural Resources
Chena Hot Springs has received water right for both the cold and hot water supply, as per LAS#25325 (for the geothermal fluid) and LAS #25326 (for the cold water infiltration gallery). The application was submitted on August 8th, 2005, and after a two week public comment period and internal review the permit was approved. In the State of Alaska, a geothermal resource is defined as a resource with a temperature above 120°C, which is hotter than the resource being used for the power plant at Chena Hot Springs. For this reason, a standard water rights permit is adequate for use of the geothermal resource.

### Underwater Injection Control NOA

Agency: Environmental Protection Agency
Chena Hot Springs has submitted a Notice of Intent (NOA) with the EPA, and completed an 'Inventory of Injection Wells' form for EPA. EPA will allow Chena to operate under this NOA for this project, provided 'no process changes will occur to the fluid prior to injection, and nothing is added to the fluid prior to reinjection'. They have also requested updated water chemistry analytical reports.

### Permission to Construct for Injection Well for the Geothermal Fluid

Agency: Department of Environmental Conservation
Chena Hot Springs has been working closely with DEC on a reinjection strategy for the geothermal fluid. DEC will not require a permit, but will allow Chena to operate under a written'Permission to Construct' after reviewing the final plans for the reinjection system and water chemistry. This permit should be obtained by December, 2005.

### Permit for Discharge of Water into Monument Creek

Agency: Department of Environmental Conservation & Department of Fish and Game
Chena Hot Springs is seeking a permit to discharge the power plant cooling water into Monument Creek. Because the water should meet water quality standards[10], and because the water being discharged is less than 15°C, no mixing zone is required for the project[11]. A discharge permit, including a 30 day public comment period is required for any discharge into waterways in the State of Alaska. Prior to obtaining the permit, a water sample must be obtained from the infiltration gallery to ensure it meets the minimum requirements for water quality. All other cold water wells on property meet this standard, so no problem is expected in meeting this requirement. However, the infiltration gallery must be completed in order to obtain the sample. Therefore, this permit is not expected to be completed until May, 2006.

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[10] Based on similar wells located near the proposed infiltration gallery.
[11] Based on the most stringent regulation for water discharge set forward in the Alaska State Statutes.

## PART 6: OBTAINING UTILITY CERTIFICATION

In anticipation of this project, Chena Hot Springs Resort formed Chena Power, LLC. On June 22nd, 2004, the Regulatory Commission of Alaska approved Chena Power's application for a certificate of public convenience and necessity, with partial exemption from economic regulation.

Chena Power was formed to take control of generating, transmission, and electric sales at the resort. Its two primary customers are currently Chena Hot Springs Resort and Summit Telephone.

## PROJECT BUDGET AND TIMELINE

To date, Chena Power has spent $960,192 on this project, in components, labor, and in-kind donations from its sister companies, Chena Hot Springs Resort and K&K Recycling. A spreadsheet which includes a project budget and a revised timeline are included in the supplemental attachments. No invoices have been submitted to AEA to date for this project, and none will be submitted with this report.

Chena Power is still waiting to make certain it qualifies for the award before submitting any invoices for reimbursement of expenses. This is because in August, 2005 Chena Power submitted a grant application to USDA in partnership with UTC under the High Energy Cost Grant Program. If Chena Power receives the award under the USDA program, it could potentially drop Chena Power's project costs below the $1,899,065 cost share required by AEA and would make Chena Power ineligible to accept the award. Chena Power expects to receive notification by early November, 2005, on their application.

# CHENA HOT SPRINGS 400kW GEOTHERMAL POWER PLANT CAPITAL COSTS ESTIMATE

| Estimated budget | | PROJECT | completed | Oct (05) | Nov (05) | Dec (05) | Jan (06) | Feb (06) | Mar (06) | Apr (06) | May (06) | June (06) | July (06) | Aug (06) | Sept (06) | Oct (06) | Nov (06) | Dec (06) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 125172 | | **Test well program** | | | | | | | | | | | | | | | | |
| | 6025 | Well 0 drill program | | | | | | | | | | | | | | | | |
| | 6652 | Geologic Survey to locate drill site | | | | | | | | | | | | | | | | |
| | 52,000 | 11-1/2 day Drill Program (5 wells of 300ft) | | | | | | | | | | | | | | | | |
| | 8004 | crew expenses (3 total) | | | | | | | | | | | | | | | | |
| | 4442 | oil and lubricants | | | | | | | | | | | | | | | | |
| | 6796 | Geologist on site 3 days plus report | | | | | | | | | | | | | | | | |
| | 25,000 | materials (pumps, casing, ect) | | | | | | | | | | | | | | | | |
| | 943 | Dipper T Well test eq | | | | | | | | | | | | | | | | |
| | 95 | Repair, calibration of Dipper T (April '04) | | | | | | | | | | | | | | | | |
| | 15,215 | Administration (salary, 75% time, 13 wks) | | | | | | | | | | | | | | | | |
| 15,089 | | **Well Monitering Program** | | | | | | | | | | | | | | | | |
| | 12,089 | Long term pressure monitoring Eq. | | | | | | | | | | | | | | | | |
| | 1,000 | Installation | | | | | | | | | | | | | | | | |
| | 2,000 | Wellhead T,P,q gauges | | | | | | | | | | | | | | | | |
| 105,000 | | **Geothermal Well completions** | | | | | | | | | | | | | | | | |
| | 55,000 | Drill Rig (3 days) | | | | | | | | | | | | | | | | |
| | | Crew (wage and exp) | | | | | | | | | | | | | | | | |
| | | Supplies | | | | | | | | | | | | | | | | |
| | 50,000 | Centrilift Submersible Pump | | | | | | | | | | | | | | | | |
| 402,150 | | **Site Preparation** | | | | | | | | | | | | | | | | |
| | 22,500 | Steel crossbeams for foundation | | | | | | | | | | | | | | | | |
| | 12,000 | Dirtwork for foundation | | | | | | | | | | | | | | | | |
| | 41,650 | Heated concrete slab | | | | | | | | | | | | | | | | |
| | 40,000 | Wirsbo, Insullation, Installation, Wire Mesh | | | | | | | | | | | | | | | | |
| | 135,000 | Steel Building | | | | | | | | | | | | | | | | |
| | 5,000 | Transportation to Chena Site | | | | | | | | | | | | | | | | |
| | 55,000 | Building erection (labor & eq) | | | | | | | | | | | | | | | | |
| | 50,000 | Insulation | | | | | | | | | | | | | | | | |
| | 27,000 | Electric | | | | | | | | | | | | | | | | |
| | 10,000 | Control Room | | | | | | | | | | | | | | | | |
| | 4,000 | Telephone and Internet hookup | | | | | | | | | | | | | | | | |
| 497,920 | | **Battery Storage System** | | | | | | | | | | | | | | | | |
| | 367,920 | 440 GNB 2V Units (50% of new) | | | | | | | | | | | | | | | | |
| | 50,000 | Inverter System 480VDC/480VAC) | | | | | | | | | | | | | | | | |
| | 36,000 | Electronic Switchgear | | | | | | | | | | | | | | | | |
| | 2,000 | Transformers 500kVA | | | | | | | | | | | | | | | | |
| | 32,000 | Storage Modules (stainless steel) | | | | | | | | | | | | | | | | |
| | 10,000 | Installation | | | | | | | | | | | | | | | | |
| 15,000 | | **Upgrades to Existing Electric System** | | | | | | | | | | | | | | | | |
| | 7,500 | Restraping Generators to 480VAC | | | | | | | | | | | | | | | | |
| | 7,500 | Paralleling Generators | | | | | | | | | | | | | | | | |
| 180,000 | | **Geothermal Pipeline** | | | | | | | | | | | | | | | | |
| | 70,000 | 2000ft 8in supply pipeline | | | | | | | | | | | | | | | | |
| | 20,000 | Installation (Eq & Labor) | | | | | | | | | | | | | | | | |
| | 70,000 | 2000ft 8in return pipeline | | | | | | | | | | | | | | | | |
| | 20,000 | Installation (Eq & Labor) | | | | | | | | | | | | | | | | |
| 158,500 | | **Cooling Water Supply** | | | | | | | | | | | | | | | | |
| | 3,500 | 500ft 8in supply pipeline | | | | | | | | | | | | | | | | |
| | 10,000 | Installation (Eq & Labor) | | | | | | | | | | | | | | | | |
| | 70,000 | 2000ft 8in return pipeline | | | | | | | | | | | | | | | | |
| | 20,000 | Installation (Eq & Labor) | | | | | | | | | | | | | | | | |
| | 15,000 | Infiltration Gallery | | | | | | | | | | | | | | | | |
| | 40,000 | Supply Pumps -- 2 Fairbanks Morris 8in pump | | | | | | | | | | | | | | | | |
| 738,902 | | **400kW Power Plant** | | | | | | | | | | | | | | | | |
| | 168,630 | Engineering design | | | | | | | | | | | | | | | | |
| | 482,795 | Materials and Fabrication | | | | | | | | | | | | | | | | |
| | 57,477 | Commissioning and Testing | | | | | | | | | | | | | | | | |
| | 30,000 | SCADA monitering system | | | | | | | | | | | | | | | | |
| 182,712 | | **Power Plant Installation** | | | | | | | | | | | | | | | | |
| | 25,000 | Transportation to Chena Site | | | | | | | | | | | | | | | | |
| | 157,712 | Installation | | | | | | | | | | | | | | | | |
| 41,700 | | **Project Management** | | | | | | | | | | | | | | | | |
| | 5,000 | Miscellaneous Permitting | | | | | | | | | | | | | | | | |
| | 3,000 | Water Use Permit | | | | | | | | | | | | | | | | |
| | 31,200 | Administration (Salary 20% time, 24 months) | | | | | | | | | | | | | | | | |
| | 2,500 | Water Sampling | | | | | | | | | | | | | | | | |

| | |
|---|---|
| **$ 2,462,145** | **TOTAL PROJECT BUDGET** |
| **438,902** | **PROJECT EXPENSES COVERED BY UTC** |
| **$ 2,023,243** | **CHENA HOT SPRINGS PROJECT EXPENSES** |
| **$ 960,192** | **EXPENSES ALREADY INCURRED** |
| **$ 1,063,051** | **FUTURE FUNDING PERIOD** |

# SUPPLEMENTAL FIGURES

**Figure 1.** Conex Units Housing Chena Power UPS System

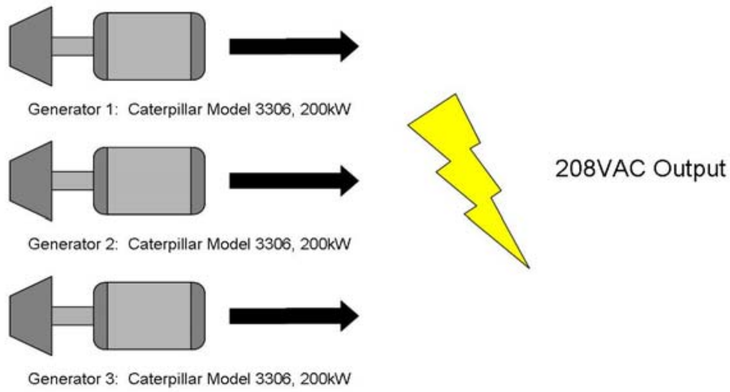


**Figure 2.** Original Configuration of the Chena Power Plant; no paralleling of generators

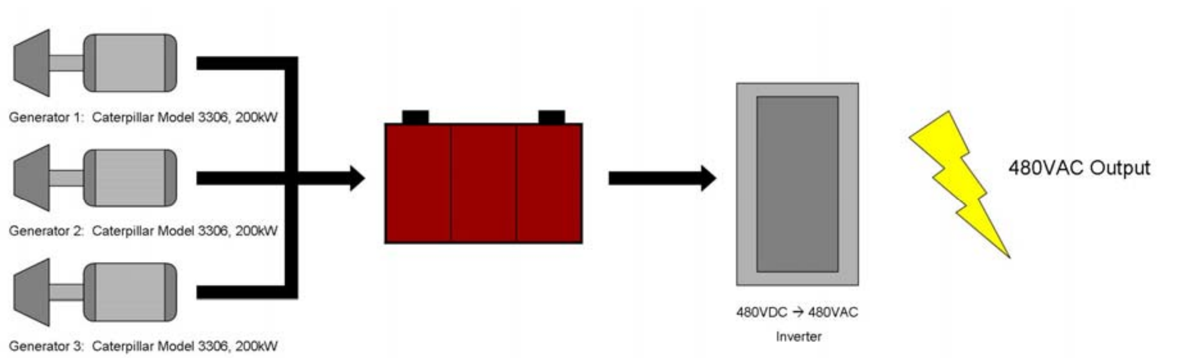


**Figure 3.** Current Configuration of the Chena Power Plant; paralleling of generators and 480VAC output

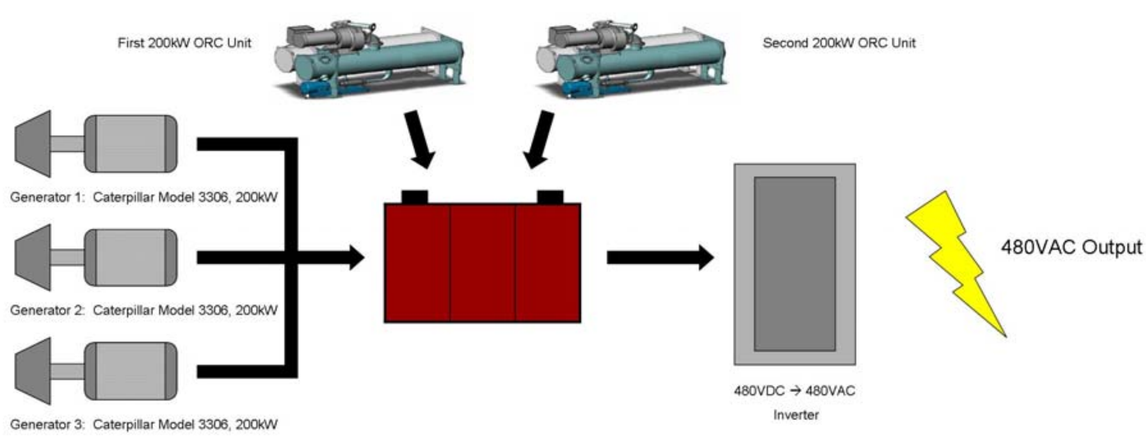


**Figure 4.** Final Configuration of the Chena Power Plant; paralleling of generators and geothermal ORC units with 480VAC output


**Figure 5.** Breaker for UPS System 480VDC → 480VAC

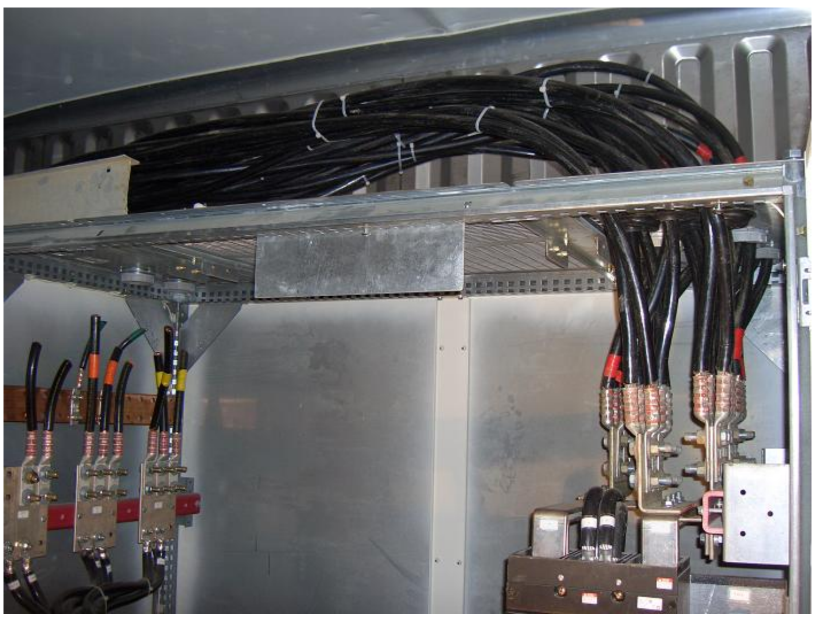

**Figure 6.** Wiring through cable tray from inverters to battery bank

**Figure 7.** Restraping Caterpillar 3360 Generators for 480VAC output


**Figure 8.** New Chena Power Double Walled Fuel Tank

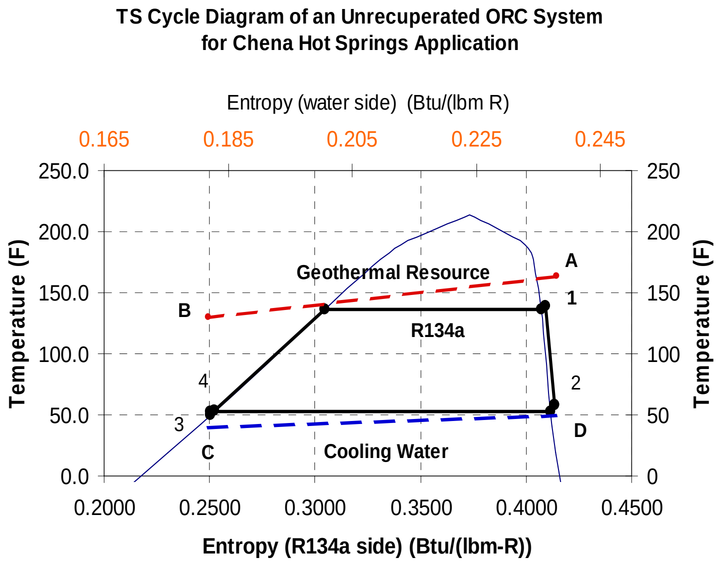


**Figure 9:** T-S diagram of the ORC for Chena Hot Springs application

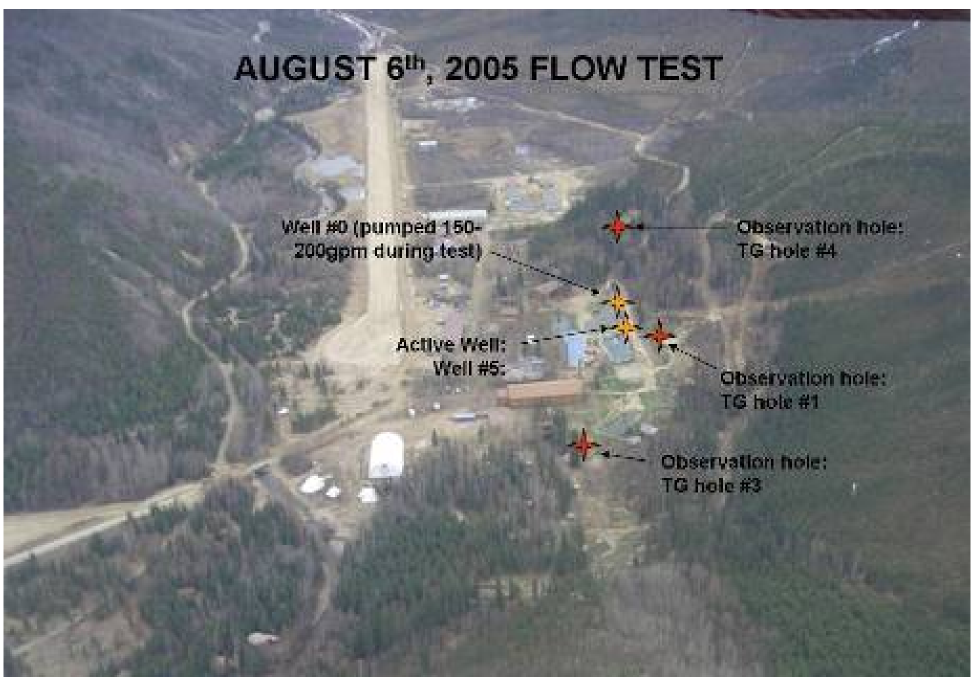


**Figure 10.** Location of Active and Observation Wells During Flow Test

**Figure 11.** Weir Box Configuration for Flow Test

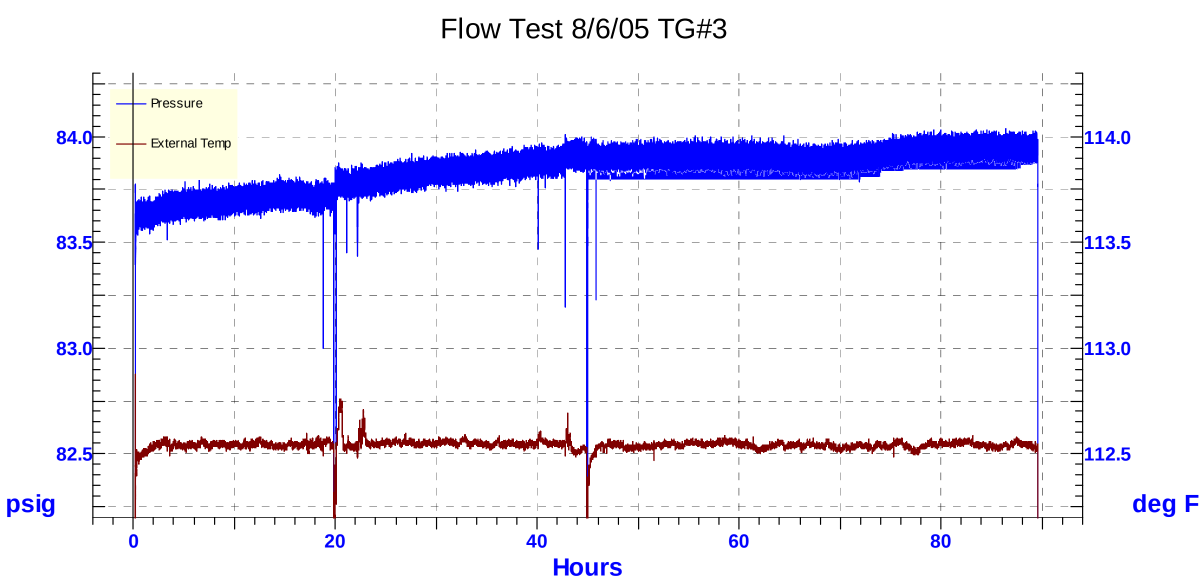


**Figure 12.** TG #3 Shows no Discernable Temperature or Pressure Drop

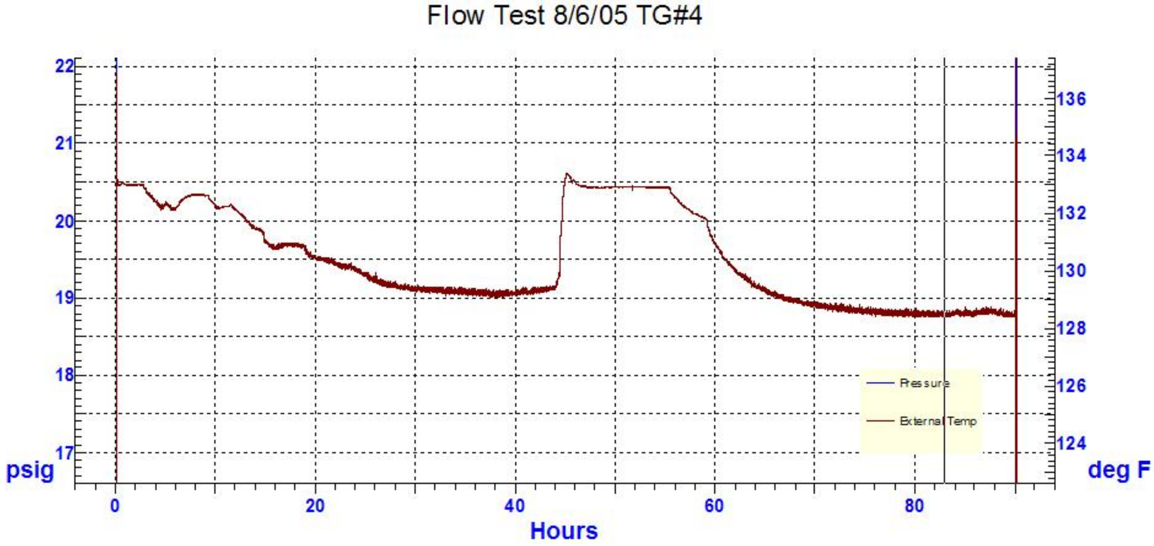


**Figure 13.** Temperature Increase in TG#4 During Flow Test

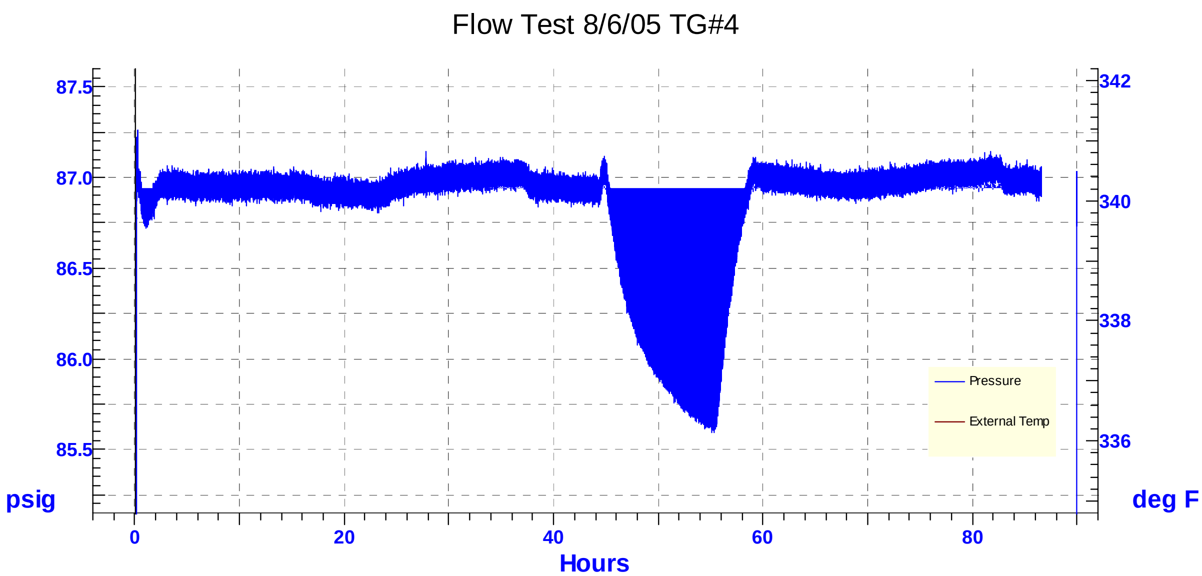


**Figure 14.** Interference Pressure Response During Flow Test

**Figure 14.** Slab poured for power plant foundation in September, 2005

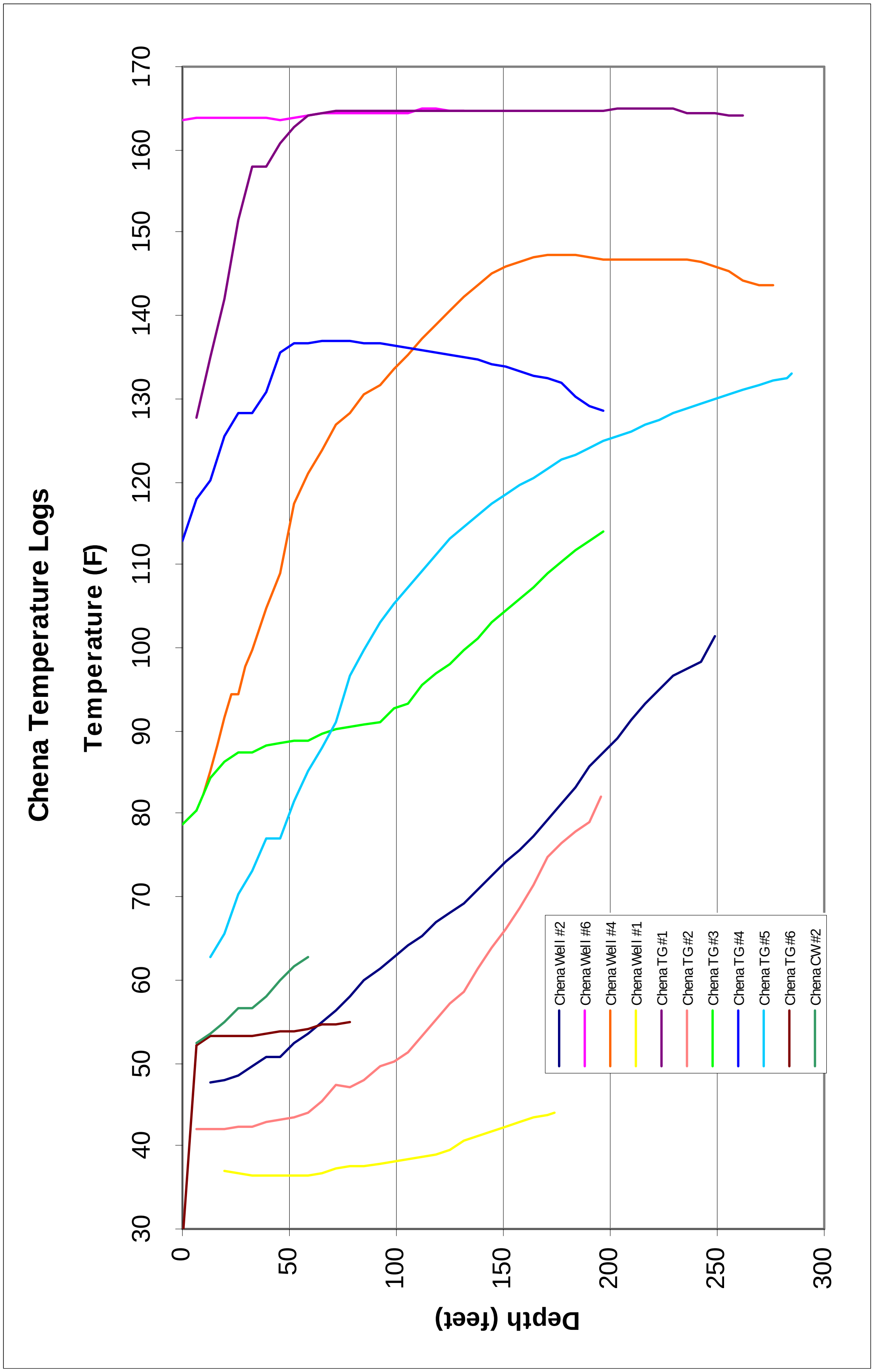


**Figure 15**. Temperature Surveys on all Wells and Temperature Gradient Holes, October, 2005

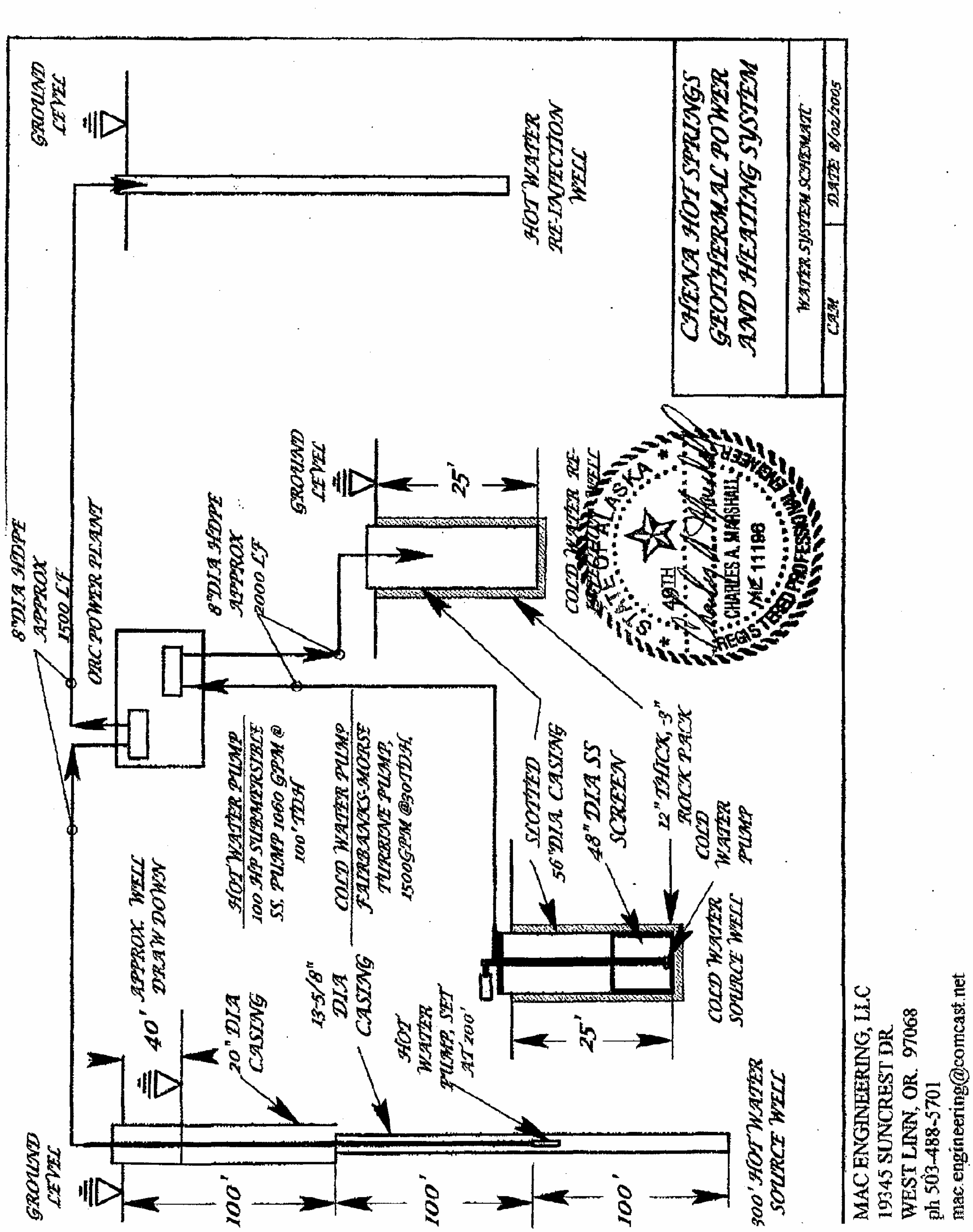


**Figure 16**. Skematic for Cold Water and Hot Water Supply for Chena Hot Springs Geothermal Power plant, by Chuck Marshall, PE